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ABSTRACT

This review of the research literature on the interaction between humans and computers discusses how man machine systems can be utilized effectively in the learning-teaching process, especially in secondary education. Beginning with a definition of man machine systems and comments on the poor quality of much of the computer-based learning material currently available, the discussion focuses on how to make optimal use of the interaction between computers and students. The discussion includes definitions and concepts of this interaction, as well as examples of the use of artificial intelligence for computer-assisted instruction in problem-solving and mathematics. Also identified are four types of interactions between humans and machines and criteria and recommendations considered important for effective interaction between students and computers. Specific uses of the computer in various disciplines, teacher attitudes towards computers, and the use of videotex are also discussed. A synthesis of these issues is provided, followed by three recommendations for making effective use of computer interactions in education in the future and an outline of some of the issues that should be considered when designing the user interface for students. A 33-item bibliography/reference list is appended. (DJR)

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MAN MACHINE SYSTEMS IN EDUCATION

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ABSTRACT

This paper explores the literature in the area of Man Machine Systems (interaction of people and computers) in Education. Some definitions and concepts of this interaction are given along with some examples of the latest artificial intelligent computer assisted instruction. A conclusion/ synthesis is given based on the common element of the literature reviewed. Some future recommendations and highlighted issues are stated.

INTRODUCTION

The purpose of this paper is to review the literature on 'Man Machine Systems' in Education. These systems identify the area of interaction between humans and machines (which are usually computers). According to the ERIC (Educational Resources Information Center) Thesaurus, the definition is "Interactive organizations of individuals and machines (usually computers) that regulate and control events as single systems." The literature examined was focused on secondary education and how Man Machine Systems are utilized effectively in the learning-teaching process. There is a problem in education in this area according to (Bork, 1984, pp.1-4) who states "(1) Extremely little good computer based learning material is available in any country. Much of the material, including commercially published material, is of very poor quality. (2) The standards currently in use in computer based learning material are extremely low and are in great danger of becoming accepted as the standards. ... (8) Authoring languages are useless in generating effective computer based learning material." This review of the literature will examine examples of state-of-the-art Man Machine interaction and conclude with some suggestions to the problems above. The chronological time frame of the literature is from nineteen seventy-four to nineteen eighty-four. The larger related area of Cybernetics and Ergonomics is not reviewed since the focus of this paper is on

educational pedagogy instead of human factors engineering interaction.

REVIEW OF THE LITERATURE

Ritz (1974) defines communication as "an interaction resulting from the exchange of ideas and information between men and/or machines." He further states that for interaction to take place, there must be the following three essential things present: (1.) The person and/or machine must be able to convey ideas. (2.) These ideas must be in the form of written or spoken words, symbols, signs, gestures, etc., and (3.) We must be able to affect the machine's or person's behaviour so that we know our communication is effective. He also stresses the fact that communications used by us must be very accurate so that we do not waste human effort and time, natural resources, materials, and money. If a person or machine keeps in perspective the answers to the questions who, what, where, when, and how when communicating, then there is less chance of anything being wasted. He also isolates one of industry's main objectives or goals as being able to produce the best quality product in the shortest time possible and at the cheapest cost possible. Ritz (1974) identifies four different types of interactions between humans and machines as "Man and Man", "Man and Machine", "Machine and Man", and "Machine and Machine" and gives examples of each.

"Man and Man" interaction usually takes the form of written or verbal communication. "Man and Machine" interaction takes place when a person is typing, inputting information on a computer keyboard, pushing buttons, or setting controls or dials on a machine. "Machine and Man" interaction takes place when the oil pressure gauge or water temperature gauge, or warning lights on engines flash communication to humans. "Machine and Machine" interaction takes place when a thermostat or temperature control starts or stops a furnace and/or air conditioner. This "Machine and Machine" interaction process is also sometimes referred to as cybernetics when one machine can control the operation of another machine. In the computer field this is very common since computers control robots and other machines in manufacturing and industry. As a conclusion, Ritz (1974) gives an example of a communications system that involves all four interactions between people and machines. This is when a student goes to school and is informed by the principal or teacher orally or in writing ("Man to Man") to be at school at a particular time. At night he/she sets the clock for the alarm to go off ("Man and Machine"). In the morning, one part of the clock turns on the alarm mechanism part of the clock ("Machine and Machine"). This causes the alarm to ring and wakes up the student ("Machine and Man").

Doring and Hicks (1976) give five important criteria for considering the interaction between the user and the machine: (1.) "Terminal", (2.) "Software", (3.) "Hardcopy", (4.) "Other peripherals", and (5.) "Support". The maxicalculators they

examined were the HP 9830, the WANG 2200, the IBM 5100, and the MCM 700. Under the criterion of "Terminal" they list the importance of: (1.) A well-defined keyboard (having a set of keys for the calculator mode and a set of keys for BASIC commands). (2.) A high speed scanning and scrolling CRT (Cathode Ray Tube). (3.) A high resolution screen that produces bright and sharp images. (4.) A "reliable cursor". (5.) "Paging and selective hole and erase". (6.) A disk drive or a cassette tape storage system. (7.) The size of memory should be stated or known so that the ability and cost of expansion is easy. (8.) The ability of the computer/maxicalculator to be portable, compact, able to withstand abuse, and operate quietly. Under the criterion of "Software", the student will be able to notice if the BASIC language is compiled or interpreted. They recommend an interpreted BASIC over the compiled BASIC. Doring and Hicks (1976) state that these maxicalculators are better than the microcomputers because the user can define function keys and key into a direct calculation mode instead of knowing a 'command language' of the minicomputer. To be able to run longer programs on these maxicalculators, a 'chaining' feature is needed to access and execute external sections of programs in data files. A user helpful mode of editing programs is needed along with a strong 'interrupter' pointing out the errors to the user. This will make the user and machine interaction smoother. They also recommend using 'benchmark' instructional programs to check the speed of the computer, the speed and efficiency of accessing its peripheral devices, and the speed for manipulating its file

systems. If the user has to wait longer for the interaction between the computer and its peripherals than the actual computing time, the user may get impatient. Under "Hard copy", (Doring and Hicks, 1976) recommend using a quiet printer (because of the school environment) and making sure that the speed of the printer is adequate for the demands being put on it. Under the heading of "Other peripherals" they state that consideration should be given to adding on more cassette tape machines, more disk drives, a television screen, and a card reader (marked or punched). Under the heading "Support" the authors point out that the seller of the machine must be able to provide adequate service, textbooks, self-instructional software and documentation of all hardware sold, possibly a user group/club, and have familiarity with the educational field.

Hugh Burns (1980) for the last three years has been working on the design, evaluation, and implementation of CAI (Computer-Assisted Instruction) programs concerned with "stimulating rhetorical invention in English composition". These types of programs first supply the student with a particular question giving the direction of inquisition and the motivation based on one of three creative/inventive writing processes such as: (1.) "Aristotle's enthymeme topoi", (2.) "Kenneth Burke's pentad', and (3.) "the Young-Becker-Pike tagmemic matrix". The user and/or the writer then types into the terminal an answer that he/she knows in the apppropriate subject matter or content. Burns (1980) states that this interaction makes the writers type in what they know previously and type in answers to questions

that they did not know the answer to. For the author, it was physically impossible to have an individualized interaction between himself and each of his students to direct the inquiry processes of his students so that they would become creative and inventive writers. The dialogue between the user and the computer program is recorded and a transcript is printed out for the student at the end of the session. This type of program is called "artificial inquiry", "electronic brainstorming", or the "Socratic Systems Incorporated" according to (Burns,1980). An example dialogue of the interaction between the computer and the student ("KAREN") is included in this article (the computer program uses "The Tagmemic Matrix" for the questions or the inquiry process). At the end of the example forty minute dialogue, the computer tells the student the percentage of elaboration (answering a question two or more times), the number of "particle questions", the number of "wave questions", and the number of "field questions". The computer prints out an eighteen page transcript for the student, when the student is ready to leave. Burns (1980), concludes by stating: "What such programs illustrate above all is that rhetorical invention and computer technology are indeed compatible; combining heuristic "modes" and computer "media" can well serve and gladly teach the inquisitive writer. Stimulating invention in English composition through computer-assisted instruction is, I'm convinced, an effective, supplementary way to begin teaching the art of systematic inquiry."

Davis et al (1981) divide the learning interactions of

students into three general categories: exploring with computers, playing games and simulations, and having practical experiences. Computer explorations take place when a given part of the curriculum has been taught by the teacher and then students are given time to explore those concepts and variations of those concepts on the computer. Games and simulations usually involve role playing activities and 'mock' situations. Practical experiences involve students' experiences outside of the classroom where real life situations are encountered and theories are put to practice. The following three criteria are given for assessing the above three methods of learning interaction:

> (1) using or applying one's knowledge or understanding rather than on recognizing or recalling something;
> (2) the analysis of a new situation not previously encountered rather than mastery of the original situation in which the connections were learned;
> (3) analyzing a complicated and noisy situation where confusion is likely to befall those who are unable to make the requisite connections.(Davis et al, 1981)

Davis et al (1981) give an example where a student that has been given the opportunity to analyze and become involved in a game simulation situation should be able to do these things better: (a.) anticipate and approximate the outcomes if a rule was changed in the simulation, (b.) anticipate and approximate the outcomes if a change in the social structure of the real world ocurred, (c.) analyze and decide on the strategies that are open for the characters involved in the simulation process, and (d.) design, create, and develop the student's own simulation game that is parallel to a real life social and/or scientific process.

The authors point out that teaching using games and simulations is very expensive when related to the good quality of software and the extra preparation time of the teachers. They also point out that not all students can move easily from the concrete level (real life situations) to the abstract/higher levels of cognitive learning (games and game simulations). They emphasize this by quoting (Livingston and Stoll, 1973): "Students of low academic ability or achievement usually do much better at learning to play a simulation game than at learning 'from' the game; their greatest difficulty is in transferring their understanding of the game to the real situation that the game represents." Davis et al (1981) show the results of the work done by (Dukes and Seider, 1978) that students prefer the games activities over any other new innovative technique in teaching and the students reflect this in their increased participation in discussions, low absence rate, and low drop-out rate.

Thomas (1983) states that there is no time spent on stressing nor teaching the area of interfacing computers with real physical phenomena in computer science/computer literacy courses in secondary schools. He argues that more time spent in the physical sciences (chemistry, physics, and biology) and mathematics courses to teach students about the logic of 'AND' gates and 'NAND' gates, the binary numbér system, and the use of integrated circuits for interfacing instead of regarding the computer as a "black box". He points out that the prices of traditional science apparatus (microscopes, oscilloscopes, etc.) have increased in past years but the prices of computers and

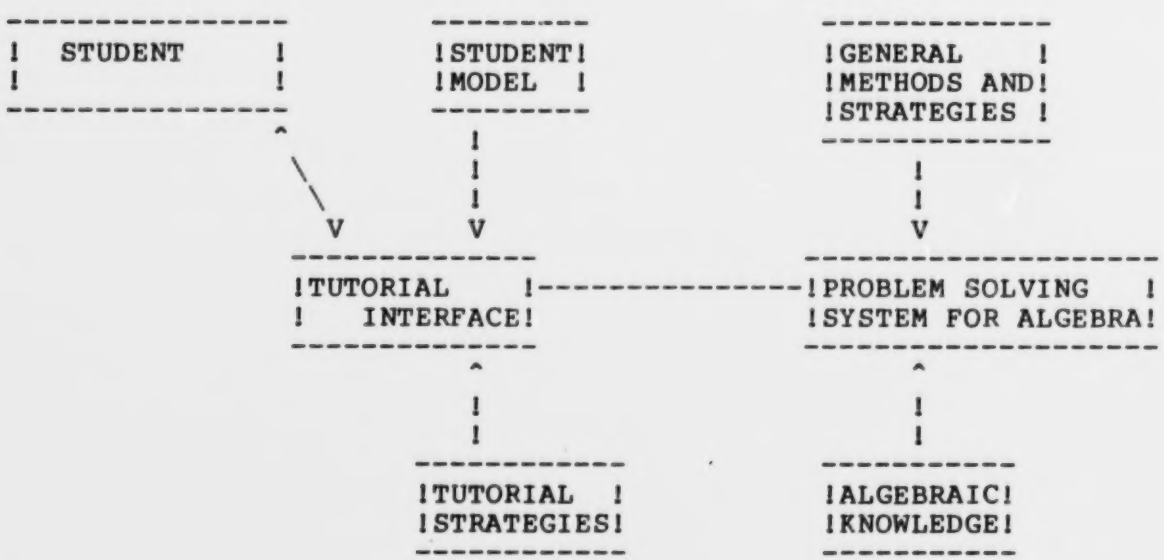
integrated circuits has decreased. He states that computers can be used as very exact timing devices, as monitoring and recording pressure/temperature devices, as light sensing devices, and as recording oscilloscope devices. His recommendation is to use the TI 99/4A Microcomputer because of the low cost, "user friendliness", and its provision of supplying sophisticated performance. Two types of computer interfacing are categorized as being either analog or digital. Thomas (1983) has supplied circuit diagrams, an assembly language subroutine, a BASIC program for using the computer as a "TIMER", and a small BASIC program to use and interpret the assembly language subroutine. He concludes by stating that the teachers should encourage students to use microcomputers as scientists and engineers use them (as monitoring devices) instead of just plugging numbers into formulae/equations and using the computer as a 'number cruncher'.

Lantz et al (1983) give an explanation on their "Intelligent CAI System For Teaching Equation Solving" by using two sysytems called a "Tutorial Interface" and a "Problem Solving System For Algebra". The student has interaction with the "Problem Solving System" through the "Tutorial Interface". As the student attempts to solve a problem, the problem solving system starts to develop a parallel solution to the student's solution. Therefore, the problem solving system develops a model of the partial solution of the student, supplies 'expert' knowledge on problem solving, and gives help to the student based on the historic knowledge of the problem solution and the knowledge of

the 'expert problem solver'. According to (Lantz et al, 1983), this complete system is an example of an effective Intelligent CAI System (ICAI). The following four types of knowledge present in their ICAI System are:

1. Domain knowledge-specific knowledge about subject matter and problem solving in the area to be taught.
2. Tutorial knowledge-knowledge about pedagogy. How and when should information be given to a student in a tutorial situation?
3. Student knowledge-knowledge about the capabilities and progress of a student interacting with a system.
4. General knowledge-depending on the system, this can range from "world knowledge" (facts) to general problem solving knowledge.(Lantz et al, 1983)

Lantz et al (1983) also give a relational component flowchart drawn below:



The authors explain the above flowchart as first the STUDENT

interacting with this system via the TUTORIAL INTERFACE. The TUTORIAL INTERFACE then makes use of TUTORIAL STRATEGIES and an interpreting program that interprets the STUDENT's responses. The system concurrently uses the ALGEBRAIC KNOWLEDGE and the PROBLEM SOLVING SYSTEM FOR ALGEBRA to keep the STUDENT MODEL updated and makes the tutoring decisions from the GENERAL METHODS AND STRATEGIES. A sample run/protocol is given showing the interaction between the ICAI and the STUDENT. Currently, (Lantz et al, 1983) state that their ICAI system is only capable of handling two variables for linear equations. Their general philosophy was to design an ICAI that would act as a flexible teacher by allowing the learner to try his/her own strategies, monitor his/her steps, and interrupt when a wrong direction is taken or when the learner cannot continue any further. When the student asks for help, only a hint is first given, then the system does the step for the student. They point out that "backtracking" or stepping backwards is also available when the student gets stuck and does not know what to do next. The concluding remarks that they make are: "While the system is still experimental, it does illustrate the potential of ICAI as a tool for augmenting the normal curriculum in a specific dicipline, by providing a flexible environment in which a student can work toward improving his skills." Their system is written in the LISP programming language and functions on a DEC-10 computer.

There are four articles edited by (Rogers and Smith, 1984) that are written by (Bork, 1984, pp.1-4), (Harding, 1984, pp.51-58), (Phillips et al, 1984, pp.173-177), and (Fiddy and Yam, 1984, pp.209-211). (i.) The article by (Harding, 1984, pp.51-58) states that a larger emphasis should be put on students to write their own programs at the secondary mathematics level to create a better understanding since students are currently getting a good foundation in "programming literacy" at the elementary and even primary grades. The author has been involved with the CATAM ("Computer Aided Teaching of Applied Mathematics") Project since nineteen sixty-nine and has developed the following model by observing students taking CATAM courses: "(1) devise mathematical model (2) decide numerical technique (3) devise algorithm, write program (4) run it, observe results, debug it (5) interpret results and relate to reality (6) perhaps change model and repeat to step (2)". He calls this model the "Investigative Approach". Harding (1984) has supplied two example programs of projects: (a.) "COMPLEX NUMBERS" and (b.) "BINOMIAL DISRIBUTIONS". Further project suggestions are given as: "Geometric and arithmetic progressions", "Solving Linear Equations", "Group Theory", "Matrices and Determinants", "Coordinate geometry", "Calculus", "Mechanics", and "Statistics".

(ii.) Phillips et al (1984, pp.173-177) report on an observation study that involved seventeen mathematics teachers in nine schools at the secondary level, teaching one hundred and seventy-four lessons from a library of ninety-seven computer programs. The lessons observed were tabulated using the SCAN

notation and other rating scales were used for collecting subjective data on attitudes of teachers and students. The average rating on attitudes of teachers reflected that most of the software materials would be used after the project finished even if teachers had to book the computer previously or move to another room to use it. Over the fourteen week school term, there was no decrease in the student's motivation and the teacher's assessment of computer aid value. After two terms, the larger number of teachers who took part in the project were still continuing to augment their teaching with the micrcomputer, using it as a teaching aid. These teachers that continued using the computer were largely effected by convenience of computer access and how the computer complemented their style of teaching. Phillips et al (1984, pp.173-177) also categorized the teacher's mode of instruction using a microcomputer as: (a.) "electronic blackboard style", (b.) "competitive style", and (c.) "investigative style". Their results showed that teachers preferred the "electronic blackboard style", the students preferred the "competitive style", and the observers of the classrooms preferred the 'investigative style". The only statistically significant result that showed a difference was the classroom observers. All the other differences were very small and insignificant. The researchers also found by doing pre-tests and post-tests in their study that the gains in achievement related to the computer-taught students were significantly higher ($P < 0.01$). In concluding, they stated that teaching using a computer will be successful in the future if the mathematics

teachers have the resources, have easy access to them, and can use them so that they can complement their own teaching style.

(iii.) Fiddy and Yam (1984, pp.209-211) explain how the medium of Prestel was used to develop the skills of numeracy and literacy for pre-school children (aged from three to six). They explain that Prestel is a data-based system that can be accessed by telephone networking in England. Information is displayed in pages on VDU (Video Display Units or Televisions) when prompted by a numeric keypad. Three programs developed through Prestel were: (1.) numeracy, (2.) pre-reading, (3.) early reading/phonics. The numeracy program consisted of showing a number of items less than or equal to nine (for example items such as houses, boats, buses, etc.) and the pupil typed in the appropriate number symbol to match the number of items. The pre-reading program used very short sentences with the same structure and the meanings were illustrated by simple graphics. For example, two sentences were given: "1. Make the roof red. 2. Make the roof pink." and a simple graphic display of a house was given. When the student typed in the answer, the graphic displayed changed to show the appropriate colored house. The early reading/phonics program emphasized the practise of primary sounds. The words and sentences were based on nursery rhymes. An example of a given sentence is "Jack and ...." and the pupil would choose the answer from "(1) Bill (2) Jill (3) Will". This program does not continue to the next line until the correct answer is typed in. All three programs do not penalize students for wrong responses since the design philosophy was ".... to

provide the child with an opportunity for learning through discovery ...." instead of through drill and practise. This project was labelled as being successful although it was emphasized that parents and/or older siblings should discuss and help the pupils understand the concepts. For example, students may learn which number symbol keys to press to get the right answer but may not learn the names of the symbols or the definitions of the words used in the pre-reading program. By having an older person reading out loud to the pupils and going over some of the meanings, the understanding will be meaningful. In conclusion according to (Fiddy and Yam, 1984, pp.209-211) currently, Dr. Z. Dienes of the T.H.E. (Tele-Homework Enterprises Ltd.) is working on activities that are designed to help teachers in school and at the same time keeping in mind the traditional educational objectives of both mathematicians and parents. Financial considerations must be highlighted as one of the constraints of this Prestel technology since the system is expensive.

(iv.) Bork (1984, pp.1-4) gives two examples of using computers in education: (1.) for an introductory level physics course and (2) for a general overview course on scientific literacy. Both of these units were created at the Educational Technology Center at the University of California. He also makes his position clear on the following eight issues: (1.) There is very little good quality computer based software anywhere in the world. Most of the existing material including commercial software is poor. (2.) There is fear that the very low standards

used in developing computer related learning materials will be adopted as 'the' proper standards. (3.) Most materials that are available are just "bits and pieces' instead of a complete collection. (4.) The computer is very flexible in the ways that it can be used in education. Decisions on how it should be used should be based on pedagogy instead of philosophy. (5.) Teacher training programs are very weak in our educational system, especially in-service training programs. (6.) In all levels of education (primary, elementary, junior secondary, senior secondary, college and university) more emphasis should be put on teaching the structure of programming. (7.) It is highly improbable that good programming structure can be taught using BASIC, therefore BASIC should be circumvented at any cost. (8.) To develop computer based materials for learning, using authoring languages is a waste of time. Bork (1984, pp.1-4) justifies the computer for being used for human learning at all educational levels (primary to university) with a variety of different types of people because of the 'interaction' created between the machine and the learner. He argues that the traditional method of teaching is passive (the learner assumes a role as spectator or absorber). By using the computer as a method of teaching, the learner's role becomes more active and interactive. The computer facilitates individualized instruction by assessing the learner's previous subject content or methods, by assessing comprehension in the current module/unit, and by assessing if the student needs more revision or if the student can go on to the next unit. Also by using this interaction between the computer and the student,

the level of student interest can be evaluated and the software module/unit can be improved by recording and saving all student responses. He also points out that we need to develop some criteria for evaluating the quality of this computer-learner relationship. In conclusion (Bork, 1984, pp.1-4) raises four issues on the future of education: (1.) There will probably be a large usage of computers used for education because they are effective due to the learner's interaction and individualization and the economics are more attractive due to the decreasing cost factor. (2.) It is not definite if the future will be desirable or not, this depends on either good or poor quality of computer based materials used for learning. (3.) The key to an excellent future in education depends on the amount of care and good quality design that is put into the materials used for computer based learning. (4.) Institutional change must take place in the educational system from within, from external pressures (including financing), from increasingly popular distance learning programs, and from an increasing direction towards mastery/criterion referencing modes.

CONCLUSIONS/SYNTHESIS

The conclusion/synthesis is based on the main strand that holds all of the literature together of how to make the use of the interaction between computers and people optimal in education. Ritz (1974) states that there must be concise communication and feedback between man and machine. Doring and

Hicks (1976) point out that elements such as hardware, software, and vendor support must be recognized as being valuable for effective interaction. Burns (1980) gives an example of student-computer interaction for stimulating a systematic inquiry/invention process for English composition. Davis et al (1981) point out that there is considerable value in the interaction between students and computer games and simulations as long as the students can relate between the concrete and the abstract. Thomas (1983) argues that greater emphasis should be put on education to use the microcomputer to communicate information as another type or style of apparatus in the science laboratory. Lantz et al (1983) give an example of an intelligent computer assisted instruction system interacting with a student in the area of linear algebraic problem solving. It also has the ability of giving hints, supplying specific steps, and 'backtracking'. Harding (1984, pp.51-58) states that computer programming in applied mathematics should be used as the vehicle for increasing the student's understanding of the theoretical concepts and increasing the interactive capability of the computer. Phillips et al (1984, pp.173-177) conducted a research study that showed by using the interactive process of a computer to teach mathematics at the secondary level, students recorded higher achievement levels and higher motivational levels. Mathematics teachers' attitudes towards the computer and their perceptions of the instructional value of the computer were both positive. Fiddy and Yam (1984, pp.209-211) used Prestel via telephone networking to interact with pre-school children at home

to develop the skills of numeracy, pre-reading, and early reading/phonics. Dr. Z. Dienes is developing similar modes of computer interaction to be used as part of the traditional school curriculum. Bork (1984, pp.1-4) emphatically states that the computer will continue to grow as an agent for human learning at all levels of education because its interaction changes the role of the student from being passive to being active. The computer also facilitates individualized instruction and the ability to create better ICAI by storing all student responses.

Furthermore, all of the above authors would agree that there is no singular specific way in which the computer is used for creating the best interaction where the learning-teaching process is at a maximum. Bork (1984, pp.1-4) states "The computer can be used in many ways in education. Philosophical discussions should not rule out certain ways. Decisions should be made on pedagogical grounds." and according to (Phillips et al, pp.173-177) "The computer appears to be a very versatile teaching aid which can be used to good effect in a number of quite different ways." (Ritz, 1974) suggests that the communicative relationship between learners and computers can take a variety of forms such as signs, symbols, written/verbal words, pictures, diagrams, etc. Lantz et al (1983) state "While the system is still experimental, it does illustrate the potential of ICAI as a tool for augmenting the normal curriculum in a specific discipline, by providing a flexible environment in which a student can work toward improving his skills."

In respect to student or learner motivation and enthusiasm,

(Davis et al, 1981) bring forward games and simulations as valid learning interactions. Phillips et al (1984, pp.173-177) also mention student enthusiasm as "Another measure of pupil's attitudes comes from their behaviour. Lessons where the computer elicited laughter, cheering, an unusual quality of pupil discussion or where it caused pupils to stay on after the end of a lesson were counted ....". Fiddy and Yam (1984. pp.209-211) state that "Children who have used the program have asked for more." This type of learner attitude is a valuable tool to be used in education.

FUTURE RECOMMENDATIONS AND ISSUES

Three recommendations made by (Bork, 1984, pp.1-4) for the future of computer interactions in education are: (1.) Good criteria/standards must be developed for producing ICAI, (2.) Institutional change must take place to incorporate greater computer interaction, and (3.) We must be aware of distant learning activities and a movement to criterion level and mastery level modes of learning. Thomas (1983) states that "The best techniques for utilizing the new capabilities within our overall math, science, and computer curriculum have yet to be developed."

Two important issues raised by (McCann, 1981) are that how much control of learning should be with the computer, teacher, and student? By using computers in education are we producing computer dependent students unable to survive in the real world? I raise the issue of distant learning. Is it an ideal learning

environment? Can or will ICAI be used on its own and replace traditonal teachers? Are games and simulations considered as good quality student-computer interactions and relationships?

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